Electrical Power Engineering (2)

Code: EP2207

Lecture: 4 **Tutorial: 4** **Total: 8**

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Per Unit quantities

Steps of converting actual single-phase system to the per unit quantities:

- Choose MVA base $\mathbf{MVA_{base}}$ for the whole system
- Choose a kilo voltage base $\mathbf{kV_{base}}$ for one section
- Calculate the voltage base in other sections in the network using the transformation ratio of transformers
- Calculate the impedance base and current base using $\mathbf{MVA_{base}}$ and $\mathbf{kV_{base}}$ in each section

$$\boxed{Z_{base} = \frac{V_{base}}{I_{base}} = \frac{V_{base}^2}{S_{base}}}$$

$$\boxed{I_{base} = \frac{S_{base}}{V_{base}}}$$

Per Unit quantities

Steps of converting actual single-phase system to the per unit quantities:

- Calculate the pu value using the general equation

$$Per\ unit\ value = \frac{\text{actual value}}{\text{base value}}$$

Per-Unit Scaling for Three-Phase Systems

To convert the actual three-phase system to the per unit quantities, perform the following steps:

- **Choose** an apparent power base "$VA_{3\text{-}base}$" **for the three phase** for all parts in the system
- **Choose** a line-to-line voltage base $V_{L\text{-}base}$ for one section in the circuit
- **Calculate** the voltage base in other sections in the network using the transformation ratio of transformers considering the method of winding connection

Per-Unit Scaling for Three-Phase Systems

To convert the actual three-phase system to the per unit quantities, perform the following steps:

- Calculate the impedance base and current base in terms of VA_{base} and V_{base} in each section of the power system using the following equations:

$$\boxed{I_{base} = \frac{S_{3-base}}{\sqrt{3}V_{L-base}}}$$

Per-Unit Scaling for Three-Phase Systems

To convert the actual three-phase system to the per unit quantities, perform the following steps:

For star connection:

$$Z_{\text{base}} = \frac{(V_{L-\text{base}})^2}{S_{3-\text{base}}}$$

For delta connection:

$$Z_{base} = 3\frac{(V_{L-base})^2}{S_{3-base}}$$

- Calculate the pu value using the general equation

$$\text{Per}-\text{unit value} = \frac{\text{actual value}}{\text{base value}}$$

Per Unit quantities

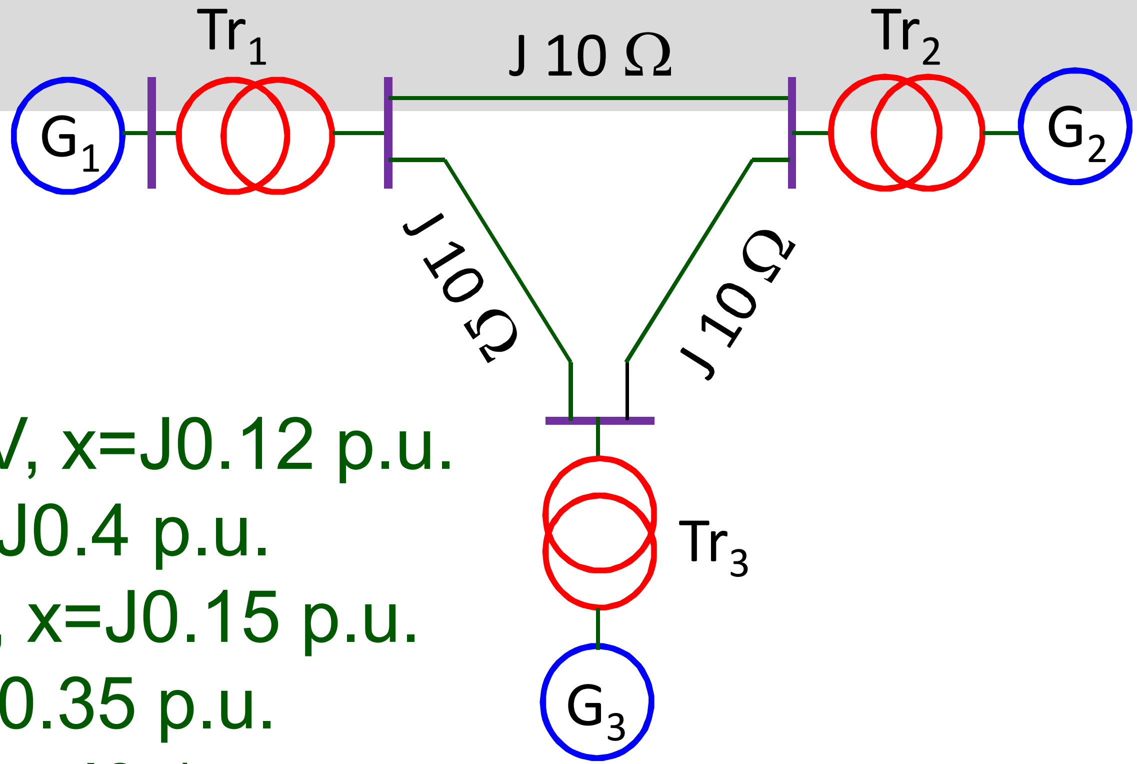
Changing the base

If the values of the parameters are given for certain bases and it is required to calculate the values for other bases, a certain relation can be used

This relation modifies the old value according to the ration between new and old bases according to the following relation:

$$\boxed{X_{pu(new)} = X_{pu(old)} \frac{VA_{b(new)}}{VA_{b(old)}} \left(\frac{V_{b(old)}}{V_{b(new)}} \right)^2}$$

Per Unit quantities



Example:

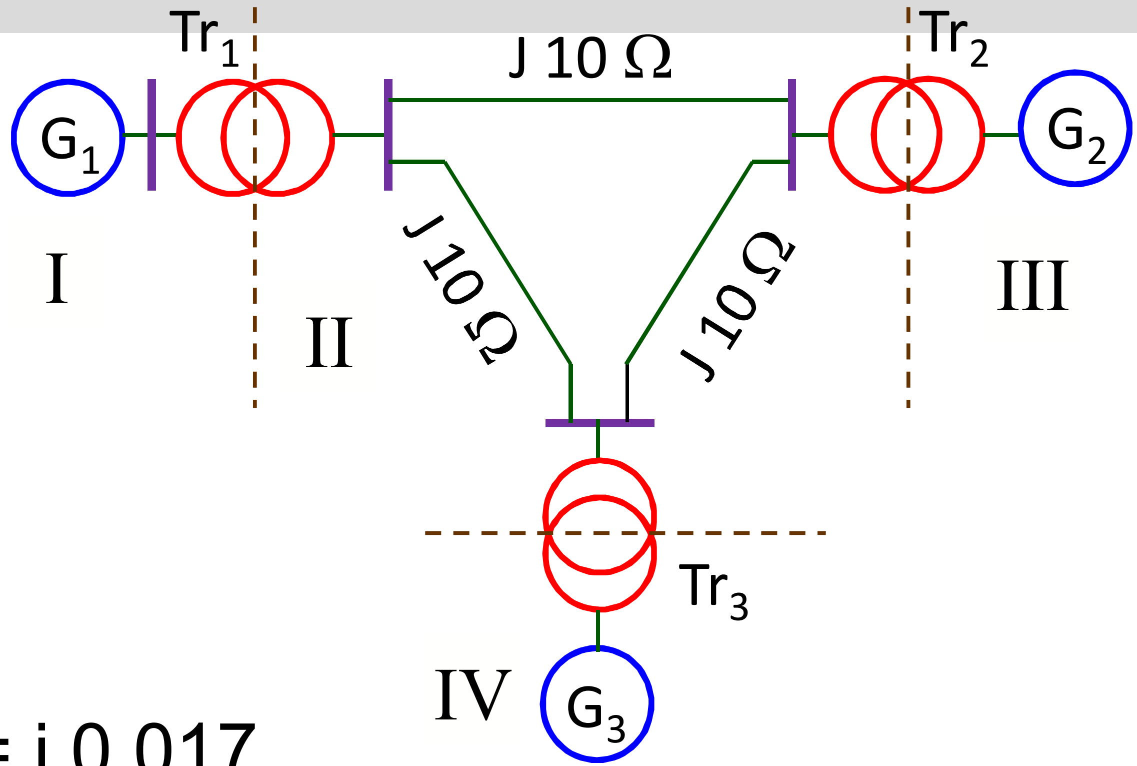
For the network shown, the data are:

Tr_1: 20 MVA, 11/110 kV, x=J0.12 p.u.
G_1: 20 MVA, 11 kV, x=J0.4 p.u.
Tr_2: 10 MVA, 6/110 kV, x=J0.15 p.u.
G_2: 10 MVA, 6 kV, x=J0.35 p.u.
Tr_3: 5 MVA, 3/110 kV, x=J0.1 p.u.
G_3: 5 MVA, 3 kV, x=J0.3 p.u.

Draw the impedance diagram for the network assuming bases of 20 MVA and 11 kV in the G_1 area.

Per Unit quantities

Solution



MVA_b = 20 MVA

kV_{b-1} = 11 kV

kV_{b-II} = 110 kV

kV_{b-III} = 6 kV

kV_{b-IV} = 3 kV

$X_L = 10 * 20 / (110)^2 = j\ 0.017$

$X_{g1} = 0.4 * 20 / 20\ (11/11)^2 = j\ 0.4$

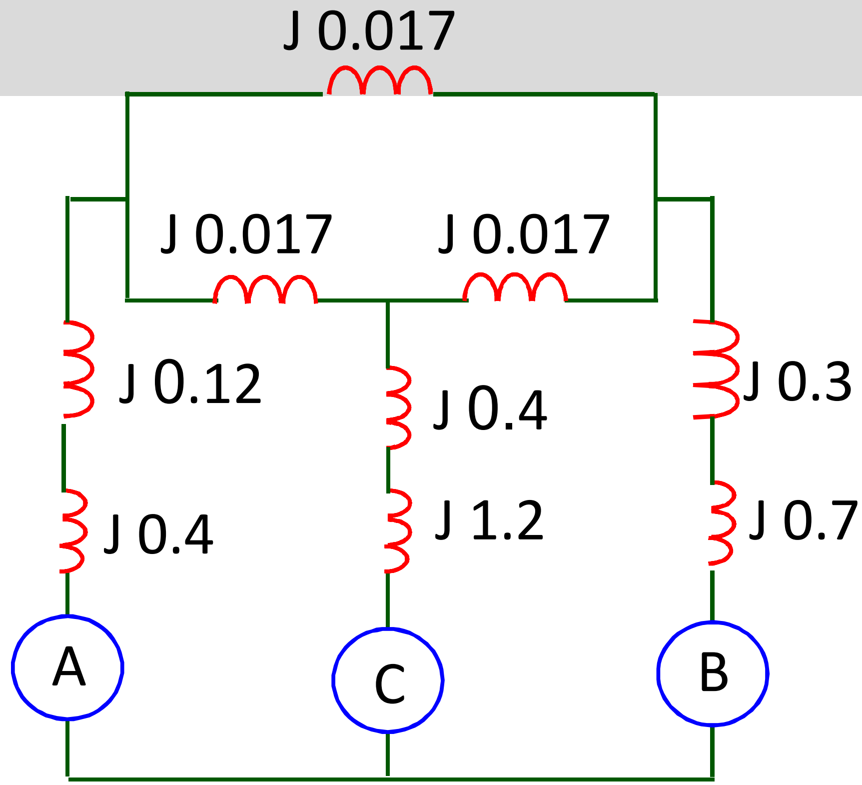
$X_{g2} = 0.35 * 20 / 10\ (6/6)^2 = j\ 0.7$

Per Unit quantities

Solution

$$X_{g3} = 0.3\,\frac{20}{5}\left(\frac{3}{3}\right)^2 = j1.2$$

$$X_{tr1} = 0.12\,\frac{20}{20}\left(\frac{110}{110}\right)^2 = j0.12$$



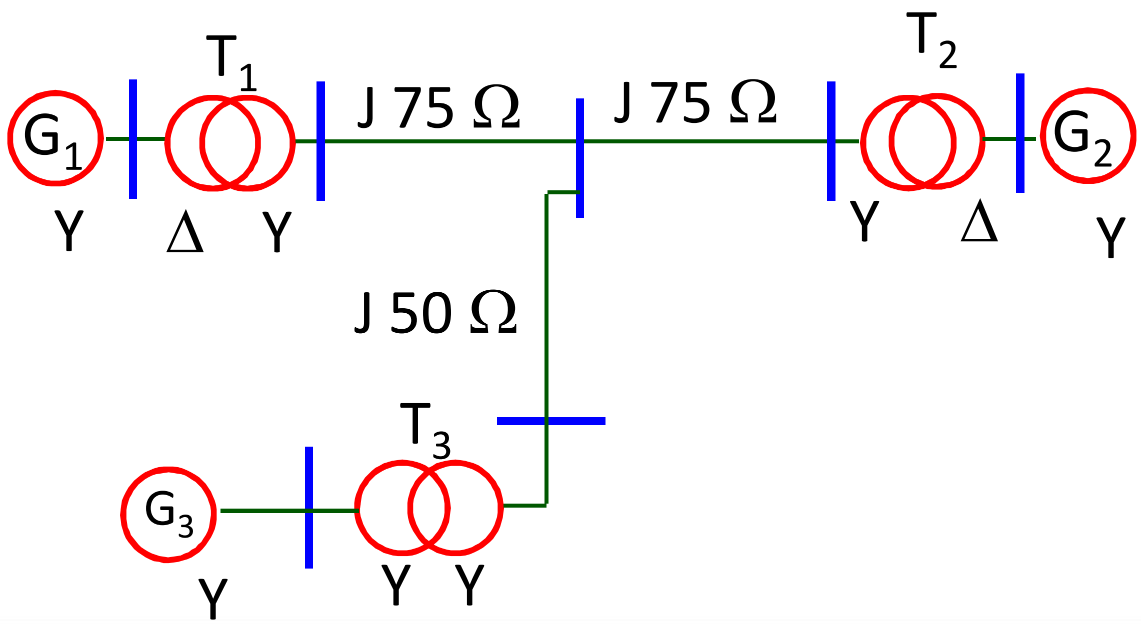
X_{tr2} = 0.15 * 20 / 10 $(110/110)^2$ = j 0.3

X_{tr3} = 0.1 * 20 / 5 $(110/110)^2$ = j 0.4

Example: The power system shown in the figure has the following ratings:

Generator G_1	**200 MVA, 20 kV, $X_d = 15\%$**
Generator G_2	**300 MVA, 18 kV, $X_d = 20\%$**
Generator G_3	**300 MVA, 20 kV, $X_d = 20\%$**
Transformer T_1	**300 MVA, 220Y/22 kV, $X_d = 10\%$**
Transformer T_2	**Three single-phase units each rated 100 MVA, 130 Y / 25 Δ kV, $X = 10\%$**
Transformer T_3	**300 MVA, 220/22 kV, $X = 10\%$**

The transmission line reactances are as indicated in the figure. Draw the reactance diagram in per unit choosing the generator 3 circuit as the base.



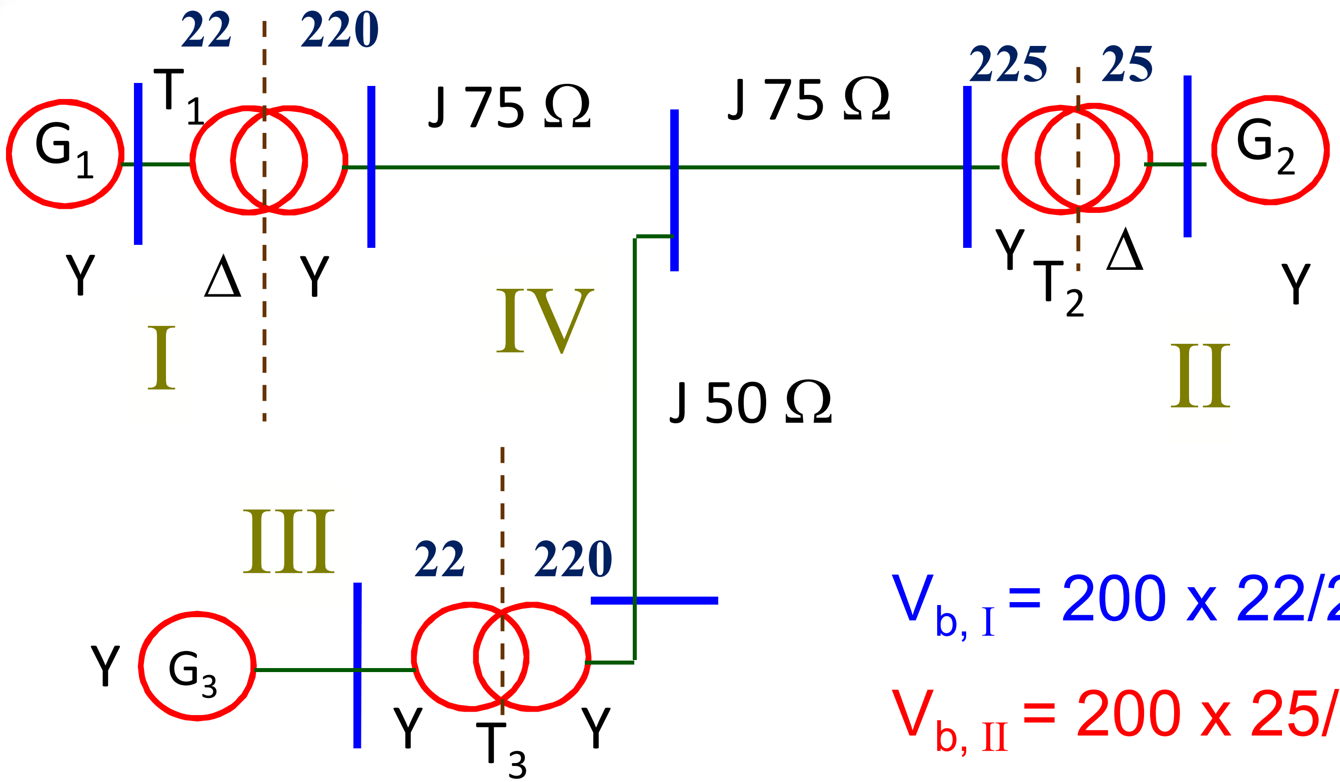
$MVA_{base} = 300$ MVA

H.V.S. of transformer T_2 is Y connected

Its rated line to line voltage is $\sqrt{3} \times 130 = 225$ kV

L.V.S. is connected in Δ → Its line voltage is 25 kV

$V_{b,\,III} = 20$ kV, $V_{b,\,IV} = 20 \times 220/22 = 200$ kV



$V_{b,\,I} = 200 \times 22/220 = 20$ kV

$V_{b,\,II} = 200 \times 25/225 = 22.22$ kV

$V_{b,\,I} = 200 \times 22/220 = 20$ kV

$V_{b,\,II} = 200 \times 25/225 = 22.22$ kV

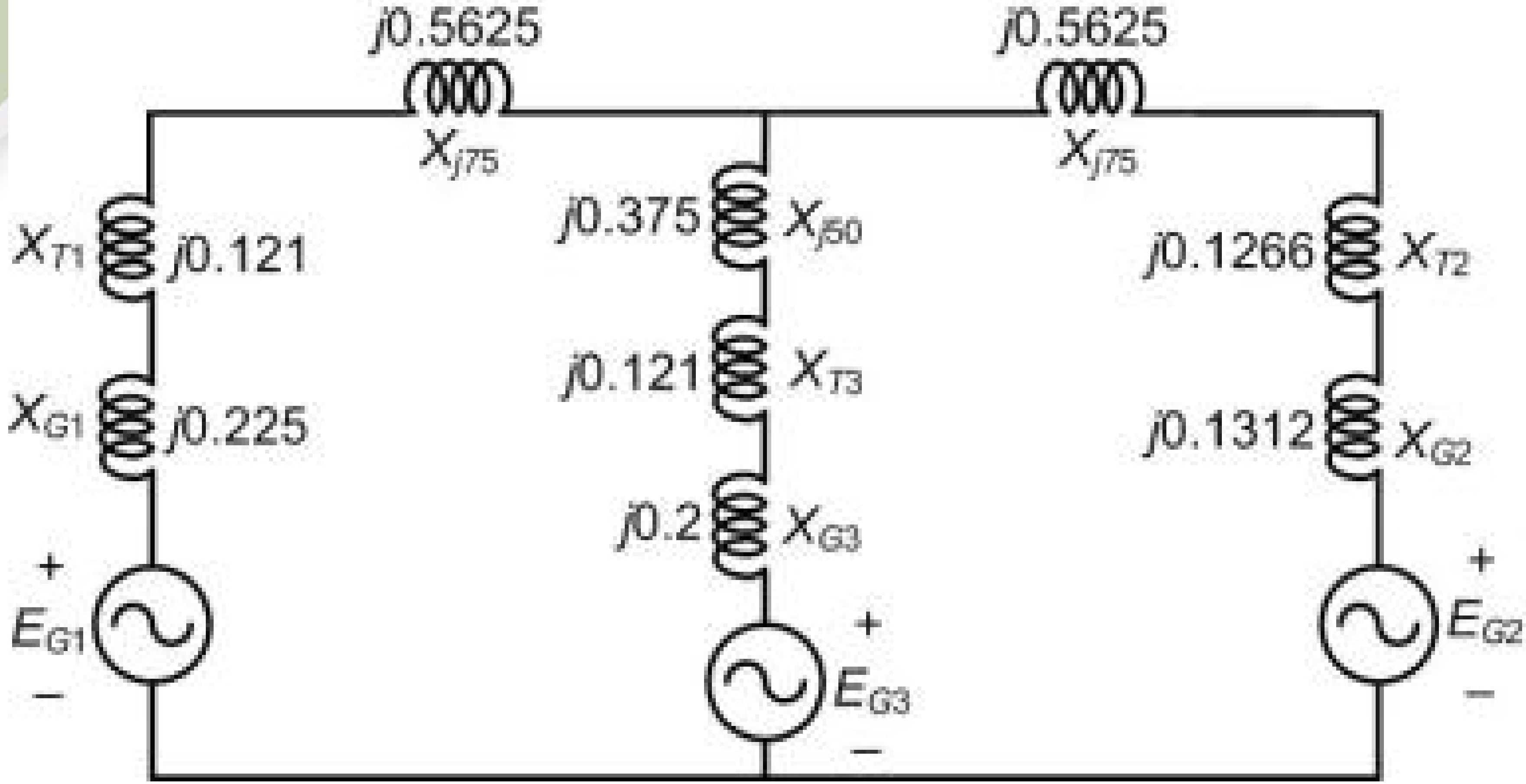
Generator G_1	$X_{G1} = 0.15 \times \frac{300}{200} = 0.225$
Generator G_2	$X_{G2} = 0.2 \times \left(\frac{18}{22.22}\right)^2 = 0.1312$
Generator G_3	$X_{G3} = 0.2$
Transformer T_1	$X_{T1} = 0.1 \times \left(\frac{220}{200}\right)^2 = 0.121$

Transformer T 2 $X_{T2} = 0.1 \times \left(\frac{25}{22.22} \right)^2 = 0.1266$

Transformer T 3 $X_{T3} = 0.1 \times \left(\frac{22}{20} \right)^2 = 0.121$

$$Z_{base} = \frac{(200 \times 10^3)^2}{300 \times 10^6} = 133.33$$

$$X_{j75} = \frac{75}{133.33} = 0.5625 \qquad X_{j50} = \frac{50}{133.33} = 0.375$$



j0.5625
Xj75
j0.5625
Xj75
XT1
j0.121
j0.375
Xj50
j0.1266
XT2
j0.121
XT3
XG1
j0.225
j0.1312
XG2
j0.2
XG3
+
EG1
−
+
EG3
−
+
EG2
−